RTCA, Inc.
1140 Connecticut Avenue, N.W., Suite 1020
Washington, D.C. 20036, U.S.A

CONCEPT OF OPERATIONS
Night Vision Imaging System for Civil Operators

Updated: June 15, 2000

FOREWORD

This document was prepared by the RTCA Special Committee 196 convened in accordance with Terms of Reference issued mmm dd, 1999.

EXECUTIVE SUMMARY

TABLE OF CONTENTS

1.0 Introduction

1.1 Purpose

The purpose of this document is to describe the concept of operations supporting the implementation of an aviation night vision imaging system (NVIS) technology into the national airspace system (NAS). This paper discusses the intended uses, capabilities, employment, training and other supporting agencies for NVIS. The focus of the paper is on the interactions among all components of NVIS during various phases of flight to ensure safe and efficient implementation. The goal of implementing NVIS into the NAS is to improve operator's situation awareness during night VFR operations without compromising the safety of non-NVIS night VFR operations. Simply stated, NVIS is an aid to VFR flight.

1.2 Background [W Wallace & K Poulsen]

a. Use NPRM draft background
b. Refer to introduction & abstract of DO/FAA/RD-94/21 "Night Vision Goggles in EMS helicopters" research paper.
c. NVIS technology improvements (Army justification/NVIS background)
d. Pilot population – new entries from military have mostly NVG time as opposed to unaided night time
e. Demand for more night flying on civilian operators
f. Reducing CFIT – safety recommendations from Joint Safety Analysis teams for Safer Skies.

2.0 Terminology

2.1 Night Vision Goggles (NVG)

2.1.1 General

An NVG is a binocular appliance worn by a pilot that enhances the pilot's ability to maintain visual surface reference at night.

2.1.2 Type

"Type" refers to the design of the NVG with regards to the manner in which the image is relayed to the operator. A Type 1 NVG is one in which the image is viewed directly in-line with the image intensification process. A Type 1 NVG is also referred to as "direct view" goggle. A Type 2 NVG is one in which the image intensifier is not in-line with the image viewed by the operator. In this design, the image may be reflected several times before being projected onto a combiner in front of the operator's eyes. A Type 2 NVG is also referred to as an "indirect view" goggle.

2.1.3 Class

2.1.3.1 General

Class is a terminology used to describe the filter present on the NVG objective lens. The filter "cuts off" light wavelengths below a certain level in order for the cockpit lighting to be designed and installed in a manner that does not adversely affect NVG performance.

2.1.3.2 Class A

Class A NVGs incorporate a filter which imposes a 625 nanometer cutoff. Thus, the use of colors in the cockpit (e.g., color displays, color warning lights, etc.) is severely limited.

2.1.3.3 Class B

Class B NVGs incorporate a filter which imposes a 665 nanometer cutoff. Thus, the cockpit lighting design may incorporate more colors since the filter eliminates some yellows and oranges from entering the intensification process.

2.1.3.4 Class C

Class C NVGs incorporate a variation of a Class B filter but also incorporates a notch filter in the green spectrum that allows a small percentage of light into the image intensification process. Therefore, a Class C NVG allows operators to view fixed heads-up display symbology through the NVG without the energy adversely affecting NVG performance.

2.1.4 Generation

Image intensification devices were first fielded in the Vietnam era. These were large, heavy and poorly performing devices that were unsuitable for aviation use, and were termed Generation I (Gen I), referring to the level of technological development. Gen II devices represented a significant technological advancement and provided a system that could be head-mounted for use in ground vehicles. Gen III devices represented another significant technological advancement in image intensification, and provided a system that was designed for aviation use. Although not yet fielded, there are prototype NVGs that include technological advances that may necessitate a Gen IV designation if placed into production. Because of the variations in interpretations as to generation, NVGs should not be referred to by the generation designation.

2.1.5 OMNIBUS

The term OMNIBUS refers to a US Army contract vehicle that has been used over the years to buy NVGs. Each succeeding OMNIBUS contract included NVGs that demonstrated improved performance. There have been four contracts since the first in the late 1970s, the most current being OMNIBUS IV. There may be several variations of NVGs within a single OMNIBUS purchase, and some NVGs from previous OMNIBUS contracts have been upgraded in performance to match the performance of goggles from later contracts. Because of these variations, NVGs should not be referred to by the OMNIBUS designation.

2.2 Aviation Night Vision Imaging System (NVIS)

The Night Vision Imaging System is the complete collection of equipment required to operate with NVGs. The system includes NVGs and NVIS lighting.

2.3 NVIS Lighting

2.3.1 General

If a lighting system has been modified or designed for use with NVGs, it is designated as NVIS lighting. This can apply to both interior and exterior lighting.

2.3.2 Design Considerations

The NVG filter drives the cockpit lighting design, it is important to know which goggle will be used in which cockpit. Since the filter in a Class A NVG allows wavelengths above 625 nanometers into the intensification process, it should not be used in a cockpit designed for Class B or C NVGs. However, since the filter in a Class B and C NVGs is more restrictive than that in a Class A NVG, the Class B or C NVG can be used with either Class A or Class B cockpit lighting designs.

2.3.3 Compatible

In the military, an NVIS lighting system that meets all of the requirements in the appropriate specification (e.g., MIL-L-85762A) is said to be "compatible." The same holds for civilian applications, and a NVIS lighting system that meets the requirements of the Minimum Operational Performance Specifications is said to be compatible. If a lighting modification does not meet all requirements in the specification it is not compatible, even if the lighting does not adversely affect NVG performance. In this case the lighting may still be acceptable if properly tested and deemed to be safe and effective.

It is very important to understand that compatibility with NVGs is only part of the equation. Of equal significance is instrument readability. It is critical to safe and effective flying that operators be able to adequately read their instruments, especially the primary flight instruments. Instrument readability is addressed in the specification, so if a system is compatible, this concern is managed. If concessions are made, it is critical not to compromise instrument readability for NVG compatibility.

3.0 System Description

3.1 Night Vision Goggles [J Winkel]

3.2 Lighting [C Antonio]

3.3 Night Vision Alternative Systems

3.3.1 Night Vision Goggle Head Up Display (NVG HUD)

A Night Vision Goggle Head Up Display (NVG HUD) consists of an electro-optical display device designed to serve as an aid to situational awareness while flying with NVGs. The HUD assembly is typically physically mounted to one of the optical tubes of the NVG, fitting over the objective lens. The purpose is to project critical, real-time, flight and navigation symbology data into the optical path of the NVG. The HUD allows the pilot to obtain primary flight information while flying head-up, thus minimizing the requirement to look under the goggles to obtain the same information from the instrument panel.

A typical NVG HUD consists of a display unit and a display driver. The display unit is a small Cathode Ray Tube (CRT) with associated optical combiner components. The display driver receives flight and navigation information from a signal data converter and drives the CRT to display the desired flight symbology. The imagery from the CRT is then reflected off a very small combiner element that is positioned in the center of the HUD's optics and placed in the NVG optical path (Field of View). "Cat Eyes" (fixed wing implementation) and helmet visor type displays (emerging technology) may also be used with similar components.

The military has proven the NVG HUD to be of great benefit in increasing situational awareness while maintaining the head up and eyes out of the cockpit. Maneuvers can be flown with more precision and aggressiveness with a HUD than without. One of the most common causes of military accidents involving NVG flight operations has been an inadequate instrument scan/cross check which requires looking under the goggles for aircraft not equipped with a HUD device.

Although the NVG HUD can be of great benefit, just like the NVG, it requires proper design, cockpit integration, and training to be effective in improving situational awareness. Some essential tenets concerning NVG HUDs that have been proven through military field experience and testing are listed below:

a. The HUD must be tested to ensure that the HUD combiner transmission does not significantly affect NVG performance. Testing should include HUD transmission and spectral characterization (Class A or B filters), gain, resolution, system FOV, symbology FOV, magnification, and distortion.
b. A symbology brightness control must be provided that can handle a wide range of ambient lighting conditions.
c. Symbology displayed should be tailorable to the mission and have a declutter capability. Centrally located symbology may occlude real life obstacles.
d. There shall be no perceivable latency in symbol movement for primary flight information.
e. Symbology displayed on the HUD must be as accurate as that displayed on the instrument panel.

f. The HUD must be capable of being displayed over either eye. Eye dominance is a critical factor in pilot performance with NVG HUD. Eye dominance must be determined prior to use.

g. The connection between the HUD and the aircraft must not impede emergency egress.

h. The NVG eyepiece must be of sufficient diameter to preclude symbology occlusion. Tests have demonstrated the minimum eyepiece diameter to be 25-mm.

3.3.2 Forward Looking Infrared (FLIR)

This CONOPS only addresses NVGs and does not include FLIR thermal imaging devices. However, FLIR thermal imaging devices are considered complimentary sensors when used in conjunction with NVGs, and can aid mission accomplishment through their integration. FLIR technology is based on the fact that all objects warmer than absolute zero emit heat. FLIR can discriminate between objects with a temperature of less than one-degree difference or of the same temperature if they emit heat at different rates. The rate of emission depends upon the composition of the individual objects. FLIR sensors detect differences in the thermal properties of these materials and create an image on either a head-up, helmet-mounted, or head-down display. This process called thermal imaging, results in a monochromatic image for the aircrew (shades of gray or green depending on the display type). When used in conjunction with NVGs, the FLIR image is normally presented on a head-down multifunction display. FLIRs can allow detection, recognition, identification, and classification of targets, scenes, or activities that would otherwise be concealed by darkness and may not be visible using NVGs. FLIRs are sensitive to emitted energy whereas NVGs are sensitive to reflected energy. For this reason, depending on the ambient conditions, one device may provide a better visual picture than the other. This advantage will often change during the period of a single night. When FLIR images are used in conjunction with NVGs, the FLIR presentation must be tested to ensure that it does not adversely affect NVG performance. The table below shows a comparison of NVG and FLIR technology.

NVG	FLIR
Sensitive to reflected energy	Sensitive to emitted energy
Visible light and near IR	Mid to far IR
Images reflective contrast	Images thermal contrast
Requires at least some illumination	Totally independent of light
Penetrates moisture more effectively	Penetrates smoke and haze
Attenuated by smoke, haze, and dust	Attenuated by moisture (Humidity)

Table 3-1 Comparison of NVG and FLIR Technology

3.4 NVIS Capabilities

NVGs provide the user an image of the outside scene that is much better than that provided by the unaided dark-adapted eye, but not as good as that provided during daylight. Since the user is able to see the night environment better, situational awareness is improved and, as a result, many mission capabilities are enhanced.

3.4.1 Assumptions

When discussing mission capabilities that are enhanced with the use of NVGs, the following is assumed:

a. Aircraft internal lighting has been modified or designed to insure it does not adversely affect NVG performance, and external lighting has been properly shielded from the cockpit.
b. Environmental conditions are adequate for the use of NVGs (e.g., enough illumination is present, weather conditions are favorable, etc.).
c. A proper preflight has been performed on the NVGs, and they have been properly aligned and focused.

Even when insuring that these conditions are met, there still are many variables that can adversely affect the safe and effective use of NVGs (e.g., flying towards a low angle moon, flying in a shadowed area, flying near extensive cultural lighting, flying over low contrast terrain, etc.). It is important to understand these assumptions and limitations when discussing the capabilities provided by the use of NVGs.

3.4.2 Improved Situational Awareness

The term "situational awareness" is defined a number of different ways, depending on the mission, community or intent. A good definition for the civil community and one that is being used more routinely in the military is the following:

"Operator situational awareness (SA) comprises detecting information in the environment, processing the information with relevant knowledge to create a mental picture of the current situation, and acting on this picture to make a decision or explore further."

The use of NVGs provides aircrew a means to visualize the night scene, thus significantly improving SA. All the other capabilities that are enhanced when using NVGs are a direct result of this improvement in situational awareness. Examples of capabilities that are enhanced include:

a. Maneuverability
b. Terrain and Obstacle Avoidance
c. Visual Navigation
d. Target/Area Detection and Identification
e. Airborne Traffic Detection and Identification
f. Emergency situations

3.4.3 Maneuverability

The use of NVGs provide for an increase in aircraft maneuverability not previously possible during night operations. This will allow for quick responses to mission demands or potentially dangerous situations, while reducing the probability of entering an unusual attitude. Additionally, maneuvering can be accomplished with much less risk of inducing vertigo.

3.4.4 Terrain and Obstacle Avoidance

One of the greatest advantages of using NVGs is the early detection of terrain and/or obstacles that would otherwise provide a hazard to night operations. Being familiar with the area is very important, particularly when operating at low altitudes (e.g., landing in a LZ). However, obstacles can appear almost over night in some areas (e.g., new tower or wire), and being able to visualize the area provides an increased safety factor. Additionally, if forced to fly in an unfamiliar area, goggles can provide additional information that could be critical to the safe and effective operations.

3.4.5 Visual Navigation

NVGs aid in night navigation by allowing the aircrew to visualize waypoints and features that would otherwise not be seen. This improves mission effectiveness by reducing the chance of becoming lost and by insuring a more timely response. Map correlation becomes easier, as does information relayed by ground or other airborne sources. The visual information provided by NVGs may be critical if navigational equipment is not working correctly or it is not sophisticated enough to provide reliable information.

3.4.6 Object/Area Detection and Identification

Being able to visually locate and then identify objects or areas critical to mission success will enhance operational effectiveness.

3.4.7 Airborne Traffic Detection and Identification

By using NVGs, operators can keep track of other aircraft in the area more easily. Additionally, with proper exterior lighting modifications or using preplanned exterior lighting selections, it may be possible to safely and effectively co-locate several aircraft in a fairly small area (e.g., disaster relief).

3.4.8 Emergency Situations

Should an emergency arise that requires an immediate landing, NVGs provide aircrew with a means of visually locating a safe landing area, and then the means to conduct a visual landing. Additionally, should an emergency occur while maneuvering the aircraft, NVGs provide a visual scene that may allow the operator to place the aircraft in a flight position that will allow quick response to the problem.

3.5 NVIS Limitations

3.5.1 System Design Characteristics

3.5.1.1 Reduced Visual Acuity (Resolution)

Resolution refers to the capability of the goggle to present an image that makes clear and distinguishable the separate components of a scene or object. The best visual acuity aircrew can expect with NVGs is considerably less than normal daytime visual acuity (20/20). However, the best unaided eye has a nighttime resolution of only 20/200 whereas newer generation NVGs approach visual acuity of 20/25, when optimally adjusted.

3.5.1.2 Reduced Field of View (FOV)

Unaided field of view covers an elliptical area that is approximately 120° lateral by 80° vertical, whereas the field of view of an NVG is typically 30° to 45° (depending on the model and type) and is essentially circular. Both the reduced field of view of the image and the resultant decrease in peripheral vision that is consistently usable can increase the susceptibility of aircrew to misperceptions and illusions.

3.5.1.3 System Weight & Center of Gravity

The increased weight and forward CG of head supported devices have detrimental effects on pilot performance due to neck muscle strain and fatigue. There is also an increased risk of severe neck injury in crashes. The disadvantages on increased helmet weight and CG, however, are offset by the enhanced visual capability for night flying.

3.5.1.4 Monochromatic Image

The NVG image appears in shades of green. Since there is only one color, the image is said to be "monochromatic". This color was chosen mostly because the human eye can see more detail at lower brightness levels when viewing shades of green. Color differences between components in a scene helps one discriminate between objects and aids with depth perception and distance estimation. The lack of color variation in the NVG image will degrade these capabilities to some extent.

3.5.2 Operational Conditions

3.5.2.1 Illumination Level

NVGs require illumination to produce an image. There are two types of illumination that NVGs can use: natural illumination and artificial illumination. The main sources of natural illumination include the moon, stars, and atmospheric reactions. Since the NVG is sensitive to any source of energy in the visible and near infrared spectrums, there are many types of artificial illumination sources which may impact NVG performance (flares, ordnance, IR searchlights, laser pointers and illuminators, infrared beacons). Although the NVGs will still function with lower levels of illumination, the quality of the image will be effected, particularly the amount of scene detail.

3.5.2.2 Weather

As a result of the variable effects of moisture on different wavelengths, near infrared energy will pass through light moisture more easily than visible wavelengths. Consequently, what may be a visible area of light fog or rain during daytime may be virtually invisible to aircrew viewing the same scene at night with NVGs. Added to the dilemma is the fact that the thinner areas of moisture may mask areas that have a heavier moisture content. This can result in a gradual loss of scene detail as the weather system is penetrated, ending in a situation where there is virtually no visual information.

3.5.2.3 Inadvertent IMC

The best ways to avoid inadvertent flight into IMC conditions are by obtaining a thorough weather brief (including pilot reports), and being familiar with weather patterns in the local flying area. However, there are subtle changes to the NVG image that occur during entry into IMC conditions aircrew should learn to recognize. By doing so, they may be able to ascertain their predicament before things worsen. Some of the more obvious changes to the image include the onset of scintillation, loss of scene detail, and changes in the appearance of halos.

3.5.2.4 Airborne Obscurants

An NVG, like the eye, responds to reflected energy, and any obscurant affecting unaided vision will likely affect the NVG image – but not always. It is difficult to accurately predict the effect an obscurant may have on NVG performance due to variability in the size of each individual particulate and variability in the concentration of the particulates. Moisture has a varied effect. NVGs can “see through” light moisture such as thin clouds or fog very well. On the other hand, a heavy rain shower will block both near infrared and visible energy, thus affecting the NVG image. Airborne obscurants containing denser particulates such as dust, sand, or smoke will have the same effect as heavy rain by physically blocking the energy. The size and concentration of the particles will determine the degree of impact.

3.5.2.5 Terrain Contrast

Contrast is one of the more important influences on the ability to correctly interpret the NVG image, particularly in areas where there are few cultural features. Any terrain that contains varying albedos (e.g., forests, cultivated fields, etc.) will likely increase the level of contrast in an NVG image, thus enhancing detail. The more detail in the image, the more visual information aircrew have for maneuvering and navigating. Low contrast terrain (e.g., flat featureless desert, snow covered fields, water, etc.) contains few albedo variations, thus the NVG image will contain fewer levels of contrast and less detail.

3.5.2.6 Moon Azimuth and Elevation

When present, the moon is the primary source of illumination in the night sky. However, the moon can have a detrimental effect on night operations depending on its relationship to the flight path. When the moon is on the same azimuth as the flight path, and low enough to be within or near the NVG field of view, the effect on NVG performance will be similar to that caused by the sun on the unaided eye during daytime. The brightness of the moon drives the NVG gain down, thus reducing image detail. In addition, the blooming effect from the moon may be large enough to fill the entire image.

3.5.2.7 Aircraft Design Constraints (cockpit design, lighting, windscreens)

Factors such as external lighting, cockpit lighting and instrument location have the potential to adversely impact NVG gain and thus image quality. How well the windscreen, canopy, or window panels transmit near infrared energy can also effect the image.

3.5.2.8 Cultural Lights

Cultural lighting has different effects depending on many variables, and can be used in certain situations to the advantage of NVG equipped aircrew. The more important variables include brightness, color, location, quantity and proximity. Cultural lights include such things as city lights and vehicle lights.

3.5.2.9 Skyglow

Skyglow is an effect caused by solar light once the sun passes below the horizon. The effect remains until the sun is approximately 13° below the horizon. For this reason, the effect lasts well beyond official sunset in the middle latitudes. In the northern and southern latitudes, the effect may last days or months, depending on the time of the year and the sun’s position.

3.5.3 Physiological and Other Conditions

3.5.3.1 Crew Coordination

The high demands of an NVG mission requires good crew coordination between the crew, controlling agencies and any coordinating ground personnel. Loss of crew coordination during a critical phase of flight can severely impact performance of the task at hand or maneuver and possibly lead to a mishap. NVG pre mission briefs must be very thorough and cover many topics not ordinarily covered during daytime missions (e.g. moon illumination, angle, navigation methods etc).

3.5.3.2 Fatigue

There are physiological limitations that occur during the hours of darkness that may impact the NVG mission. Among these are the effects of fatigue, working outside the body's normal circadian rhythm envelope. Fatigue, a common problem during nighttime operations, can significantly degrade performance. However, the degree of degradation can be controlled to some extent if methods are developed that aid with the recognition and management of fatigue.

3.5.3.3 Overconfidence

After some NVG experience has been acquired, to include some flights in low illumination conditions, there is a natural tendency to be overly comfortable when flying in high illumination conditions or conditions similar to a previous flight.

3.5.3.4 Spatial Disorientation

Maintaining spatial orientation requires inputs from both components of the visual system, central (focal) and peripheral (ambient) vision. Central vision is primarily a conscious function and consists largely of object recognition. Peripheral vision is primarily a subconscious function and uses multiple inputs that help define spatial orientation. Maintaining spatial orientation while flying with NVGs requires complex conscious processing of data from various instruments and displays. The task of maintaining spatial orientation now competes with the usual tasks of navigation and flying the aircraft.

3.5.3.5 Depth Perception & Distance Estimation

Contrary to popular belief, aircrew due have the ability to perceive depth and distance when using NVGs. However, these capabilities are degraded to varying degrees.

3.5.3.6 Complacency

Complacency allows for acceptance of situations that would normally not be permitted, especially on an NVG flight. Attention span and vigilance are reduced, important elements in a task series are overlooked, and scanning patterns which are essential for situational awareness break down (usually due to fixation on a single instrument, object or task). Critical but routine tasks are often skipped.

3.5.3.7 Task Saturation

????

3.5.3.8 Lack of Proficiency

????

3.5.3.9 Lack of Experience

High levels of proficiency will help to offset the performance degradation associated with nighttime operations, however, in addition to proficiency, it is necessary to have a well balanced experience base. This requires aircrew to see the whole range of NVG effects, limitations, and illusions before they are truly qualified. Factors such as moon angle, illumination levels, terrain types, and cultural features should all be considered. Aircrew should be exposed to as many different variations as possible.

4.0 Operations

4.1 Personnel Considerations

4.1.1 Minimum Crew

The minimum crew for night vision goggle operations should be the higher of either the minimum crew specified by the aircraft type certificate or the minimum crew required for the approved aircraft operation.

4.1.2 Pilot Qualifications [NPRM]

4.1.3 Instructor Qualifications [NPRM]

4.1.4 Flight and Duty Time Limitations & Rest Requirements

The current flight crew flight time, duty time, and rest requirements applicable to the operation being conducted are considered adequate for night vision goggle operations.

4.2 Generic Operating Procedures

4.2.1 Normal Procedures

4.2.1.1 Pre-Flight Planning

4.2.1.1.1 Departure/Destination Weather

4.2.1.1.2 Night VFR

4.2.1.1.3 Illumination criteria

4.2.1.1.4 NVIS pre-flight

4.2.1.1.5 Aircraft Pre-flight

4.2.1.1.6 Min. Equipment

4.2.1.1.7 Route Planning

4.2.1.1.8 Obstacles (man-made vs terrain)

4.2.1.1.9 Risk Assessment

A risk assessment is suggested prior to any NVIS operation. The risk assessment should include as a minimum:

a. Illumination Level
b. Weather
c. Operator recency of experience

d. Operator experience with NVG operations
e. Operator vision
f. Operator rest condition and health
g. Windscreen/window condition
h. NVG tube performance
i. NVG battery condition
j. Types of operations allowed
k. External lighting environment

4.2.1.2 Departure

4.2.1.2.1 Controlled vs. Uncontrolled Airspace

4.2.1.2.2 Heliport vs. Remote Area considerations

4.2.1.3 Enroute

4.2.1.3.1 Mountainous Terrain

4.2.1.3.2 Overwater

4.2.1.3.3 Deteriorating Weather

4.2.1.3.4 Low illumination

4.2.1.3.5 Snow, Haze, Fog & Smoke

4.2.1.4 Arrival

4.2.1.4.1 Airport Landings

4.2.1.4.2 Lighted Heliports

4.2.1.4.3 Low Ambient Illumination Sites

4.2.1.4.4 Reconnaissance

4.9.5 Landing

4.9.5.1 Lighting

4.9.5.2 Aircraft External

4.9.5.3 Other Vehicles

Oil Rigs

4.2.2 Emergency Procedures

4.3 Operating Environment Considerations

4.3.1 Off Airfield/Unprepared Sites [?]

4.3.2 Winter Operations

Flying operations involving NVG in winter conditions provide unique issues and challenges to pilots. Operations above 60 degree latitude also adds additional considerations.

4.3.2.1 Snow

Due to the reflective nature of snow, it presents pilots with significant visual challenges both enroute and in the terminal area. During the enroute phase of a flight the snow will cause distractions to the flying pilot if any aircraft external lights(i.e. anti-collision beacons/strobes, position lights, landing lights, etc.) are not compatible with NVGs. In the terminal area whiteout landings can create the greatest hazard to unaided night operations. With NVGs the hazard is not lessened, it can be more disorienting due to light(s) reflecting off the snow swirling around the aircraft during the landing phase. Any emergency vehicle beacons/strobes in the terminal area will simply exaggerate the effect.

4.3.2.2 Ice Fog

Ice fog presents the pilot with hazards normally associated with IMC in addition to problems associated with snow operations. The highly reflective nature of ice fog will further aggrevate any lighting problems. Ice fog conditions can be generated by aircraft operations under extremely cold temperatures and the right environmental conditions.

4.3.2.3 Icing

Airframe ice is difficult to detect while looking through NVGs. The pilot will need to develop a proper cross-check under the NVGs to ensure airframe icing does not exceed operating limits for that aircraft. Pilots should already be aware of icing indicator points on their aircraft. These areas require consistent oversight to properly determine environmental conditions.

4.3.2.4 Low Ambient Temperatures

Cold temperatures can create unique problems for NVG users. Depending on the cockpit heating system, fogging of the goggles can be a problem and this will significantly reduce the NVG effectiveness. Another issue with cockpit temperatures is the reduced battery duration. Operations in a cold environment will require additional battery resources.

4.3.3 High Latitude Operations

4.3.3.1 Training

Maintaining currency and proficiency with NVGs during the summer months will challenge pilots and operators. Operators are unable to use NVGs due to insufficient night flying environment available. A properly structured training program is required to re-orient pilots back to NVG operations for the winter flying season.

4.3.3.2 Northern Lights

Northern lights provide additional illumination for NVG operations. Unfortunately this illumination source is unpredictable and can be disorienting due to its movement.

4.4 Industry Considerations

4.4.1 Agriculture

The aerial application of chemicals is highly dependant on, and limited by, the stability, or instability, of the air at ground level. The economic liability of damage to non-target areas caused by wind driven drift of the product once it is released from the aircraft severely limits the application times available to many operators. The ability to conduct spray operations at night, due to typically low winds and the lack of thermals, with the aid of Night Vision Imaging Systems would greatly increase the number of usable hours an operator could have aircraft working.

Night applications would not necessarily be limited to the spraying of traditional crops. The same stable atmospheric conditions present at night are beneficial to operations involving the spraying of herbicides over forests and right of ways. It may also be desirable to apply pesticides at night to reduce the risk of humans being exposed to the material. As an example, large-scale operations to eradicate insects such as the gypsy moth in state and national forests would be viable candidates for night operations. There are currently government operated mosquito controls employing Night Vision Goggles and the possibility of civil operators following suit certainly exists.

4.4.2 Air Medical Operations

The air medical industry with its 24 hour operations is a likely candidate for the implementation of night vision technology. The primary interest within the air medical community stems from the desire for enhanced obstacle detection and avoidance.

4.4.3 Fire Fighting

The airborne fire fighting community views night vision technology as a means to extend the operating hours of aerial application. Currently night fire fighting activities are limited due to the inability of flight crews to detect obstacles. The fire fighting units also have a need, similar to the air medical industry, to respond to emergency situations on a 24 hour basis.

4.4.4 Law Enforcement

In order to improve the overall range of mission capabilities in the Law Enforcement Community, the use of Night Vision devices were implemented. Of the devices used, FLIR and NVG's, night vision goggles have perhaps improved the pilots situational awareness during night operations the most.

Night vision goggles allow the pilot to maneuver close to the ground with almost the same ease and safety afforded him during day operations. The pilot is able to navigate at night using the same visual navigation cues as he would in the day; familiar roads and landmarks used as waypoints appear as seen in the day. Pilots are now able to respond to ground personnel and electronic sensor information in a more timely and direct manner and doing so with tactics normally used in daytime law enforcement missions.

Goggles have enhanced the overall mission performance of law enforcement. Pilots are capable of flying, at night, to some of the most remote and sparsely populated areas in the

US. They are able to visually navigate there way to the target location and perform their usual mission in a safe and expeditious manner.

Key Points:

a. Improved Situational Awareness
b. Safety
c. Maneuverability
d. Navigation
e. Flight Into Terrain Avoidance
f. Terrain Masking to Avoid Detection (Sneak Up on them Boys)
g. Multi-Helicopter Operations
h. Air to Ground Agent Tactical Operations
i. Air to Air Operations in Multi-ship flights
j. Personnel and Vehicle detection and apprehension
k. Swat Team and Covert Operations
l. Night Visual Acuity from 20/200 to 20/20-40
m. Though field of view is 40º, peripheral vision is still available for visual cues.

4.4.5 Offshore

Offshore operations are conducted in a low contrast environment which is not favorable to night vision goggle application. The extensive overwater flight which is terminated at a well lighted landing site does not benefit from night vision technology as much as other applications.

4.4.6 Other

The list of industries considered is by no means exhaustive. Representatives of the above industries were consulted in the preparation of this Concept of Operations. However, other industries may well have legitimate interests and corresponding considerations for the use of NVIS.

5.0 Training

5.1 Ground Training

The ground training necessary to initially qualify a pilot to act as the pilot of an aircraft using night vision goggles must include at least the following subjects:

a. Applicable Federal Aviation Regulations that relate to night vision goggle limitations and flight operations.
b. Aeromedical factors relating to the use of night vision goggles to include how to protect night vision, how the eyes adapt to operate at night, self imposed stresses that affect night vision, effects of lighting on night vision, cues utilized to estimate distance and depth perception at night, and visual illusions.
c. Normal, abnormal, and emergency operations of night vision goggle equipment.
d. Night vision goggle operations flight planning to include night terrain interpretation and factors affecting terrain interpretation.

5.2 Flight Training

The flight training necessary to initially qualify a pilot to act as the pilot of an aircraft using night vision goggles may be performed in an aircraft, flight simulator, or flight training device and must include at least the following subjects:

a. Preparation and use of internal and external aircraft lighting systems for night vision goggle operations.
b. Preflight preparation of night vision goggles for night vision goggle operations.
c. Proper piloting techniques when using night vision goggles during the takeoff, climb, enroute, descent, and landing phases of flight that includes unaided flight and aided flight.
d. Normal, abnormal, and emergency operations of night vision goggles during flight.

6.0 Other Supporting Agencies [L Faber]

6.1 Weather Facilities

Based on the intended goal for Night Vision Imaging Systems (NVIS), an enhancement or aid for night VFR operations, most operators will fly under their approved basic night VFR weather minimums. With that in mind, a pilot in command will perform the proper preflight planning, such as reviewing weather forecasts and reports. Weather information is very easily accessible from lots of sources, such as NOAA internet web sites or 1-800-WX-Brief. However, there are some new pieces of information for NVIS flying that weather facilities do provide, but a pilot would need to ask. The following weather information will be needed for preflight planning, in order to have a successful NVIS flight: Cloud Cover and Visibility during takeoff, enroute and landing phases of flight, sunset, civil and nautical twilight, moon phase, moonrise and moonset, and moon and/or lux illumination levels.

6.1.1 Cloud Cover and Visibility

Any atmospheric condition which absorbs, scatters, or refracts illumination (the amount of light which strikes an object or surface at some distance from a source, i.e. moonlight hitting the ground), either before or after it strikes terrain, will effectively reduce the usable energy available to the NVIS. In general, NVIS easily "see" clouds that are dense but may not see clouds that less dense. In the case of the more dense cloud (just as you can see the cloud unaided if there is enough light), especially if silhouetted against the night sky. However, dense clouds will reduce the amount of illumination striking the ground and therefore reducing the luminance (refers to the amount of light reflected from a surface, i.e. moonlight reflected from terrain) available for NVIS use. Thin (less dense) clouds have more space between particles. Because the near-IR wavelength is slightly longer, it is possible for the thin and wispy clouds (which may be seen with the naked eye during daytime) to be invisible when viewed through the NVIS. The invisibility of thin clouds can create a sever hazard for NVIS operations. Even though a cloud is "invisible", you may not be able to see the terrain behind it because the cloud reduces luminance, which in turn reduces scene contrast and texture. This, in turn, may produce a false perception of distance, resulting in the pilot either not seeing the terrain or thinking it is farther away than it actually is. Additionally, the cloud may get progressively thicker, allowing the pilot to progress into the cloud without initially perceiving it or the terrain beyond. If a cloud is detected, the perception may be that it is at a distance.

Fog, rain, and snow are atmospheric visibility conditions of concern for the NVIS operator. Fog, like clouds, has a similar effect on NVIS, but there is a greater tendency for fog to be less dense. It is important to know when and where fog may form in your flying area. Typically, coastal and mountainous areas are most susceptible. The effect rain may have on NVIS performance is difficult to predict. Droplet size and density are key ingredients to its visibility and invisibility. Light rain or mist may not be seen with NVIS, but will affect contrast, distance estimation, and depth perception. Heavy rain is more easily perceived due to large droplet size and energy attenuation. Snow occurs in a wide range of particle sizes, shapes, and densities. As with clouds, rain, and fog, the more dense the airborne snow, the greater the effect on NVIS performance. On the ground, snow has mixed effect depending on terrain type and the illumination level. In mountainous terrain, snow may add contrast, especially if trees and rocks protrude through the snow. In flatter terrain, snow may cover high contrast areas, reducing them to areas of low contrast. On low illumination nights, snow may reflect the available energy better than the terrain it covers and thus increase the level of illumination.

All atmospheric conditions described above reduce illumination levels. Recognition of this reduction in the cockpit is very difficult. This change is often a very subtle reduction in contrast which is not easily perceived with NVIS. A good weather briefing for these atmospheric conditions are important for a successful NVIS flight.

6.1.2 Sunset and Twilight Times

NVIS operations can be hampered by sunlight from below the horizon for up to two hours after sunset. The timing of these effects of sunsets varies depending on the latitude. As discussed in the Northern Operations section, the effect of sunset may last for weeks since the sun may not travel far below the horizon for long periods of time. If the mission is flown soon after sunset, profiles should be adjusted to allow west to east operations with the western horizon at the aircraft's six o'clock position. The sun's energy can be intense immediately following sunset, and can be sufficient to bright illuminate the objective with the light behind. If the mission is flown with the objective located in the same relative direction as the sunset, NVIS gain will be reduced by the ambient energy and the objective may not be detected (reduction of image quality). Similar effects are caused during sunrise but tend not to occur until the sun is fairly close to the horizon. Due to these effects, it is wise for the pilot to ask for civil and nautical twilight during their weather briefing. Depending on location, one might be surprised the time length from sunset this may occur. Twilight is the best light performance for NVIS and ensures the sunset is sufficiently below the horizon. Another means of getting this information is from the Farmer's Almanac.

6.1.3 Moon Phase and Moonrise/Moonset Times

Moon phase and elevation determines how much moonlight will be available (four phases: new moon, first quarter, full moon, and third quarter each lasting 7-8 days), while moonrise/moonset times determine when it will be available. The most important operational aspects of moonrise/moonset times concern times when the moon is low in the sky. Moon angles of less 30 degrees can render NVIS ineffective when in the direction of the low moon. Since the moon moves across the sky at approximately 15 degrees per hour, a low angle moon may be a factor for two hours after the moonrise or for two hours before moonset. Once again, besides a weather briefing, this information can be obtained through the Farmer's Almanac.

6.1.4 Moon and/or Lux Illumination

Many natural and artificial sources of energy combine to illuminate the night environment. Natural sources include moon, stars, solar light and other atmospheric reactions, while artificial sources include city lights, fires, weapons, searchlights, and flares.

Moon illumination reported on a weather report refers to the amount of illumination in the night sky from the moon based on the moon phase and angle above the horizon. Illumination from the moon is greatest when the moon is at its highest point (zenith) and at its lowest when the moon is just above the horizon. Illumination is also affected by phases of the moon. A relatively low light level is characteristic of the new moon phase. During the quarter, third quarter and full moon phase, good illumination is provided. Sometimes, during the third and quarter phases, the type of lunar surface (mountainous) being reflected by the sun can have an adverse effect on illumination. On a moonless night (i.e. new moon), where no cloud cover is evident, twenty percent illumination can be provided from stars.

Lux illumination refers to the direct illumination of the surface. This would include natural and artificial sources that would illuminate the surface. Depending on terrain, shadows, cloud cover and obstructions, lux percentages can be high due to artificial light sources from the surface in addition to moon and stars. Usually moon illumination percentages can be obtained from a weather briefing, if not by other means, such as Farmer's Almanac or Maritime information. Lux illumination percentiles are not as easily obtainable. One can get these from celestial web sites or data sources, or contact a military weather installation. It is highly recommended, if a pilot is fairly novice with NVIS, to look closely at the moon or lux illumination for that night and restrict themselves to at least 20 percent illumination. The more NVIS time and experience a pilot receives, the more comfortable a pilot's interpretation for these unique NVIS weather effects.

6.2 Air Traffic

The goal of using Night Vision Goggles is to enhance night VFR operations. With that in mind, this enhancement should not create undue burden or extra operational requirements to the National Airspace System (NAS). The function of air traffic, airport facilities, and airspace control shall not have any new requirements due to the use of NVG operations.

As mentioned in the background section of this document, the military has utilized many different types of goggles for over the past decades. Some of these older versions created difficulty for the user to fly into high ambient lighted, urban areas or well-lit airports. Many military airports that would be required to reduce their airport lighting, if goggle operations were to take affect around the airfield. Today's NVGs have overcome these difficulties and now are designed for high ambient external lighting performance. Thus, NVG operations should not require airports to reduce any ambient lighting in the vicinity of the airfield.

In addition, many military NVG operations at airfields would be required to announce "Goggle Operations" or "Aided Operations" to air traffic control when entering the airfield's airspace. One purpose for this practice was to alert air traffic control that the night VFR pattern would have aided (NVG operations) and unaided (non-NVG operations) traffic. Air traffic control and NVG operators perceived that the flow of VFR traffic may require different priority based on this enhanced see and avoid capability of NVGs. For example, if an aided operation wanted to land at a military airfield along with an unaided operation, air traffic may decide to give the unaided traffic priority, since the aided traffic would have better see and avoid capability to maneuver the aircraft easily. However, aircraft performance and other issues determine maneuverability and the flow of traffic is still night VFR with no extra operating requirements for the NVG operator.

Another purpose for the NVG announcement to air traffic control was to suffice any potential need for special services for an NVG operator who was intended to operate within the vicinity of the airfield (i.e., removal of runway lighting). However, in both situations, NVG operators should not impose special airfield lighting requirements nor should its priority in VFR traffic change. In essence, NVG operations should be transparent to air traffic and airspace controllers, and to airfield facility operators.

6.3 Airport